40 summary questions for Life in the Universe

(version at the end of the course)

1. We identified three key things about the Universe that makes Life possible:
   (a) atomic diversity, as produced by stars
   (b) temperature gradients and a lack of thermal equilibrium
   (c) intermediate temperature environments that are stable over long periods of time, as in planetary systems.

   Make sure you understand the overall significance of these in the big picture
2. What are the basic features of the Solar System in terms of the orbits of the planets etc? What do they suggest for how the Solar System formed around the Sun?
3. What are the different phases in the development of a planetary system out of a proto-stellar nebula? Roughly how long does this process take and how do we estimate this?
4. What produces the radial variation in chemical composition of planets/moons within the Solar System? Why must this be a non-gravitational process?
5. Why are asteroids and comets of interest in understanding the early Solar System?
6. How can we estimate the "ages" of rocks, and what does "age" mean here?
7. What is thought to be the primary origin of the atmospheres of rocky planets like the Earth?
8. Why is the mass of a planet important for the evolution of its rocky material and also of its atmosphere? What other factors are important?
9. What role(s) can tidal forces play in planets and moons?
10. What is the "greenhouse effect"?
11. Make sure you are broadly familiar with the molecular basis for DNA, RNA and proteins, and also with photo-synthesis and aerobic and anaerobic respiration (details of these latter not so important).
12. What was the Miller-Urey experiment?
13. What are some of the milestones in going from primitive life to complex organisms?
14. What is the evidence that astronomical impacts have shaped life on Earth?
15. Why is our carbon and water based Life likely to be preferred over other elements/solvents?
16. What is thought to have been the geological and atmospheric history of Mars, and of Venus, and why were these different from that of the Earth?
17. What is special about Europa and Enceladus, which make them an interesting possibility for Life? What is special about Titan? Where are these objects?
18. When were exo-solar planet systems discovered?
19. What are the different methods by which we can detect exosolar planets, both indirectly and directly? What are the relative pros and cons of each?
20. What can be learnt from observations of transiting planets in terms of their densities, and also their atmospheres?
21. What is meant by "adaptive optics"? Why is interferometry of interest?
22. Very roughly how many exosolar planets are now known? How do they broadly compare with the planets in the Solar System? What if anything can we learn from this?
23. What does "the habitable zone" mean?
24. How could we possibly detect remotely the presence of Life on exoplanets?
25. What is the Drake equation and what is SETI? What are some of the main difficulties in having meaningful two-way communication with other civilizations?
26. Why does the fusion of atomic nuclei release energy, but only up to iron (Fe)?

27. What is the Gamow Peak, and why is it relevant for determining the reaction rates for different fusion reactions.
28. Why are all fusion reactions strongly temperature dependent?
29. What is the significance of the negative heat capacity of any self-gravitating body (e.g. a star) in controlling fusion?
30. Why is there a minimum mass to the stars that can support fusion? How, roughly, does the lifetime of a star depend on its mass?
31. What are the possible end-points of stellar evolution (neutron stars etc) and why are these very compact objects?
32. What happens in a supernova, and why does this produce heavy elements beyond Iron. How else are such elements produced?
33. Why is the fusion of Carbon problematical? And why is the formation of Carbon in stars actually less difficult than you might have expected given this problem?
34. What is the evidence for the Big Bang, and how can we estimate when it occurred?
35. What is the evidence that the Universe started off in a very homogeneous state?
36. Why do we think that most of the matter in the Universe is actually "non-baryonic" (i.e. not comprised of protons neutrons and electrons)?
37. What is Ω and why does our observation that $\Omega \sim 1$ today suggest that something must have set Ω very close to unity at early times, and why does "Inflation" do this?
38. What is meant by "Baryogenesis"? Why do we think that the early Universe had a small imbalance of matter over anti-matter?
39. Why do dark matter haloes have densities of order 1000 times higher than the Universe as a whole, and what caused baryonic matter to separate from the dark matter to form concentrated galaxies (about 1000 denser still) at the centers of dark matter haloes?
40. Make sure you know roughly the order of magnitude sizes of quantities like
    (a) masses of atoms, cells, humans, planets, stars and galaxies
    (b) scales of atoms, cells, humans, planets, stars, galaxies and the horizon
    (c) ages of the Solar System, main sequence lifetime of stars, age of the Universe etc.